UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
OFFICE OF NEW REACTORS
WASHINGTON, DC 20555-0001

November 18, 2011

NRC INFORMATION NOTICE 2011-20: CONCRETE DEGRADATION BY ALKALI-SILICA REACTION

## ADDRESSEES

All holders of an operating license or construction permit for a nuclear power reactor under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of or applicants for an early site permit, standard design certification, standard design approval, manufacturing license, or combined license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

All holders of or applicants for a license for a fuel cycle facility issued pursuant to 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material."

All holders of and applicants for a gaseous diffusion plant certificate of compliance or an approved compliance plan under 10 CFR Part 76, "Certification of Gaseous Diffusion Plants."

All holders of and applicants for a specific source material license or for uranium recovery operating license or construction permit under 10 CFR Part 40, "Domestic Licensing of Source Material." Uranium recovery facilities include conventional mills, heap leach facilities, and in situ recovery facilities.

All holders of and applicants for an independent spent fuel storage installation license under 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

## PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of the occurrence of alkali-silica reaction (ASR)-induced concrete degradation of a seismic Category 1 structure at Seabrook Station. The NRC expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

**ML112241029**

## BACKGROUND

ASR is one type of alkali-aggregate reaction that can degrade concrete structures. ASR is a slow chemical process in which alkalis, usually predominantly from the cement, react with certain reactive types of silica (e.g., chert, quartzite, opal, and strained quartz crystals) in the aggregate, when moisture is present. This reaction produces an alkali-silica gel that can absorb water and expand to cause micro-cracking of the concrete. Excessive expansion of the gel can lead to significant cracking which can change the mechanical properties of the concrete. In order for ASR to occur, three conditions must be present: a sufficient amount of reactive silica in the aggregate, adequate alkali content in the concrete, and sufficient moisture.

ASR can be identified as a likely cause of degradation during visual inspection by the unique "craze," "map" or "patterned" cracking and the presence of alkali-silica gel (see Figure 1 in the enclosure). However, ASR-induced degradation can only be confirmed by optical microscopy performed as part of petrographic examination of concrete core samples.

To prevent ASR-induced concrete degradation, the American Society for Testing and Materials (ASTM) has issued standards for testing concrete aggregate during construction to verify that only non-reactive aggregates are present. These standards include ASTM C227, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)"; ASTM C289, "Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)"; ASTM C295, "Standard Guide for Petrographic Examination of Aggregates for Concrete"; ASTM C1260, "Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)"; ASTM C1293, "Standard Test Method for Determination of Length of Change of Concrete Due to Alkali-Silica Reaction"; and ASTM C1567, "Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregates (Accelerated Mortar-Bar Method)."

ASR degrades the measured mechanical properties of the concrete at different rates. Therefore, relationships between compressive strength and tensile or shear strength and assumptions about modulus of elasticity that were used in the original design of affected structures may no longer hold true if ASR-induced degradation is identified.

Technical information on ASR-induced concrete degradation appears in specialized literature, such as the U.S. Department of Transportation Federal Highway Administration's "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures," issued January 2010, and the American Concrete Institute's ACI 221.1R-98, "Report on Alkali Reactivity."

## DESCRIPTION OF CIRCUMSTANCES

After observing concrete cracking patterns typical of ASR, in August 2010, the licensee for Seabrook Station performed petrographic examinations and compressive strength and modulus of elasticity testing of concrete core samples removed from below-grade portions of the control building (a seismic Category I structure) that confirmed that ASR had caused the cracking. These concrete core samples demonstrated a substantial reduction in compressive strength compared to test cylinders cast during construction and a modulus of elasticity substantially lower than the expected value. The licensee completed a prompt operability determination that concluded margins to the code design limits remained such that the structural integrity of the control building continued to be demonstrated.

The Seabrook Station final safety analysis report specifies concrete testing during construction using ASTM C289 and ASTM C295, which were the accepted standards at the time of construction. However, ASR-induced degradation still occurred.

The licensee believes that the waterproof membrane was damaged during original installation or backfill activities causing water intrusion that resulted in the ASR problems. Water intrusion was exacerbated by the fact that dewatering channels were abandoned.

Additional information appears in the licensee's responses to requests for additional information related to license renewal, dated December 17, 2010, April 14 and August 11, 2011 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML103540534, ML11108A131, and ML11227A023, respectively), and in NRC inspection reports dated May 12 and May 23, 2011 (ADAMS Accession Nos. ML111330689 and ML111360432, respectively).

**DISCUSSION**

As noted above, ASTM has several standards for testing aggregates during construction to verify that only non-reactive aggregates are present, thereby preventing future ASR-induced degradation. However, ASTM issued updated standards ASTM C1260 and ASTM C1293 and provided guidance in the appendices of ASTM C289 and ASTM C1293 that cautions that the tests described in ASTM C227 and ASTM C289 may not accurately predict aggregate reactivity when dealing with late- or slow-expanding aggregates containing strained quartz or microcrystalline quartz. Therefore, licensees that tested using ASTM C227 and ASTM C289 could have concrete that is susceptible to ASR-induced degradation. Beginning at initial construction, licensees may implement measures to prevent ASR-inducted concrete degradation such as selecting non-reactive materials, and controlling water infiltration by protecting and preserving waterproof membranes, or adding and maintaining dewatering channels. Regardless of the measures taken during initial construction, visual inspections of concrete can identify the unique "map" or "patterned" cracking and the presence of alkali-silica gel in areas likely to experience ASR (i.e., concrete exposed to moisture). Additional information can be found in the American Concrete Institute's ACI 349.3R-02, "Evaluation of Existing Nuclear Safety-Related Concrete Structures.

In 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" (the maintenance rule), the NRC requires that licensees monitor the performance or condition of structures, systems, and components (SCCs) against licensee-established goals in a manner sufficient to provide reasonable assurance that such SSCs are capable of fulfilling their intended function. The regulations in 10 CFR 50.65 require that these goals be established commensurate with safety and, where practical, take into account industry-wide operating experience. In practice, for concrete structures, this usually translates into periodic visual inspection; however, specific inspection criteria related to ASR are generally not included. Section 1.5 of Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear

Power Plants," explains that an acceptable structural monitoring program should evaluate the results of periodic assessments to determine the extent and rate of any degradation of the structures.

Once visual indications of ASR-induced concrete degradation have been identified, additional actions to evaluate and monitor the condition, as recommended in the Federal Highway Administration report (referenced above), may include confirming the presence of ASR through microscopic examination of concrete cores; verifying the mechanical properties through testing of concrete cores; and in situ monitoring of the concrete over time, such as crack mapping and monitoring of concrete relative humidity. Nuclear power plant licensees may consider these actions to determine the remaining potential reactivity, and the rate of ASR progression. Because safety-related structures and nonsafety-related structures whose failure could affect safety-related structures are within the scope of the maintenance rule, licensees are required to monitor the condition of the structures against licensee-established goals to provide reasonable assurance that the structures are capable of fulfilling their intended functions. If ASR-induced degradation is identified in these structures, this condition monitoring would include determining the extent and rate of the degradation.

The NRC staff is currently reviewing the license renewal application for Seabrook Station submitted in accordance with 10 CFR 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." The Seabrook Station is the first plant to address ASR-induced concrete degradation as part of license renewal. The licensee for Seabrook Station is developing aging management programs that will include additional measures and actions to manage the effects of aging from ASR-induced degradation during the period of extended operation. In support of its license renewal application, the licensee for Seabrook Station will submit additional information that the NRC staff will review to ensure the licensee develops an acceptable program to manage the effects of ASR.

**CONTACT**

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below or to the appropriate Office of Nuclear Reactor Regulation project manager.

***/RA by DWeaver for/***

Vonna Ordaz, Director
Division of Spent Fuel Storage
and Transportation
Office of Nuclear Material Safety
and Safeguards

***/RA/***

Timothy J. McGinty, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

***/RA by JTappert for/***

Laura A. Dudes, Director
Division of Construction Inspection
and Operational Programs
Office of New Reactors

Technical Contact: Bryce C. Lehman, NRR
301-415-1626
E-mail: Bryce.Lehman@nrc.gov

Enclosure:
Photograph of Concrete Degradation

Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under NRC Library/Document Collections.

**CONTACT**

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below or to the appropriate Office of Nuclear Reactor Regulation project manager.

***/RA by DWeaver for/***

Vonna Ordaz, Director
Division of Spent Fuel Storage
and Transportation
Office of Nuclear Material Safety
and Safeguards

***/RA/***

Timothy J. McGinty, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

***/RA by JTappert for/***

Laura A. Dudes, Director
Division of Construction Inspection
and Operational Programs
Office of New Reactors

Technical Contact: Bryce C. Lehman, NRR
301-415-1626
E-mail: Bryce.Lehman@nrc.gov

Enclosure:
Photograph of Concrete Degradation

Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under NRC Library/Document Collections.

**ADAMS Accession No.:** ML112241029

| | | | | | |
|---|---|---|---|---|---|
| **OFFICE** | NRR/DLR/RASB | Tech Editor* | BC:NRR/DLR/RASB | D: NRR/DLR | BC:NRO/DE/SEB1 |
| **NAME** | BLehman | KAzariah-Kribbs | RAuluck | BHolian | BThomas |
| **DATE** | 09/12/2011 | 09/29/2011 email | 09/13/2011 | 09/22/2011 | 09/26/2011 email |
| **OFFICE** | BC: NRR/DE/EMCB | LA: NRR/PGCB | PM:NRR/PGCB | BC:NRR/PGCB | |
| **NAME** | MKhanna | CHawes | DBeaulieu | SRosenberg | |
| **DATE** | 09/12/2011 email | 10/03/2011 | 09/29/2011 | 10/17/2011 | |
| **OFFICE** | D:NRO/DCIP | D:DSFST:NMSS | D:NRR/DPR | | |
| **NAME** | LDudes JTappert for | V Ordaz | TMcGinty | | |
| **OFFICE** | 10/21/2011 | 11/18/11 | 10/24/11 | | |

**OFFICIAL RECORD COPY**

**Photograph of Concrete Degradation**

**Figure 1 Patterned cracking indicative of ASR-induced degradation (generic example–NOT from nuclear industry)**